

Ringdown Cavity for Isotopic Ratio Measurements of Carbon and Oxygen

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Molecular and isotopic spectroscopy in the midinfrared (3–7 micrometer wavelength) has been extremely useful for many quantitative gas-detection applications in fields as diverse as astrobiology, geology, atmospheric science, pollution control, environmental monitoring, and industrial process control. Variations in isotopic ratios of $^{12}\text{C}/^{13}\text{C}$ and $^{16}\text{O}/^{18}\text{O}$ in Martian soil samples could be important clues to the planet's geologic and biologic history. Such variations would be expected to be generated in a sample by any process of elemental transfer whose rate-limiting step is diffusion controlled, including past or present volcanism, freeze/thaw cycles, incorporation of carbon dioxide into the soil from the Martian atmosphere, enzymatic reactions, or respiration. Isotopic variability could also be caused in a sample by its having been mixed with other reservoirs of carbon or oxygen.

The typically strong absorption lines in the midinfrared spectral region allow for sensitive detection without the need for complex, alignment-sensitive, multipass sample absorption cells. The diode laser light sources used for spectroscopy in this spectral region typically require cryogenic cooling, making them difficult, cumbersome, and expensive, and thus limiting their usefulness. On the other hand, in the near-infrared at 1.3- and 1.55-micrometer wavelengths, where inexpensive room-temperature laser sources are readily available, the molecular absorption lines are orders of magnitude weaker than those in the midinfrared, and they can be used only with long-path multipass absorption cells. Typical long-path multipass cells, such as White cells, Harriot cells, etc. are large, cumbersome, and alignment sensitive. The relatively new technique of ringdown cavity spectroscopy affords

another solution to the problem of achieving very long effective absorption path lengths.

Laser spectroscopy offers important advantages over conventional mass spectrometry for measurements on the surface of a planet. Importantly, because of the high spectral resolution of the laser spectrometer, the detailed and complex sample preparation and purification required for reliable mass spectrometry is unnecessary, because contaminant gases do not interfere with the measurement. The goal is to develop a prototype instrument for laser spectroscopic isotope analysis of planetary soils and ices on possible missions to Mars and/or Europa.

This project uses a ringdown cavity to provide the ultra-long effective path length needed for spectroscopy with weak infrared absorption lines, but will achieve high light throughput and high spectral resolution by locking the ringdown cavity to the narrow spectral line-width of a diode laser source.

A near-infrared spectrometer consisting of a 1.6-micrometer near-infrared room-temperature diode laser, an optical isolator, a spatial filter, and a tuned ringdown cavity has been designed and constructed. The spectrometer will ultimately be frequency locked to the continuous-wave laser source, affording both high spectral resolution of isotopic absorption lines and high optical throughput for high-sensitivity measurements.

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